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Concrete Work on the Illinois Central Railroad

Civil Engineering
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CONCRETE WORK ON THE ILLINOIS CENTRAL RAILROAD

BY

WILLIAM NEIL DUNNING

THESIS FOR DEGREE OF BACHELOR OF SCIENCE
IN CIVIL ENGINEERING

COLLEGE OF ENGINEERING
UNIVERSITY OF ILLINOIS
PRESENTED JUNE 1902

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May 30 1902

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

William Neil Dunning

ENTITLED Concrete on the Illinois Central Railroad.

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Civil Engineering

Ira O. Baker.

HEAD OF DEPARTMENT OF Civil Engineering.

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Concrete Work on the Illinois Central.

Among the Western Railroads, one of the most extensive users of concrete for structural purposes is the Illinois Central. Of the very numerous structures along its lines there are very few now standing in which stone masonry has been used, the older bridge abutments, piers, and arches and culverts having been replaced by modern structures of concrete. In the masonry built when the road was young such stones were used as could be found at points along the line and which were of such inferior quality that most of the older structures have failed and been replaced by new ones - some of timber, some of steel and some of concrete.

Early Structures

In form the older structures were such as were adopted to cut stone

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masonry rather than to concrete work, the outlines being severe and simple in the extreme. The six-foot arch culvert shown in Professor Baker's Masonry Construction is a good example of the type of that class of structure which were built about 1855 to 1870 and even later. The straight head walls, timber invert, and projecting bench walls of this type are characteristic of the former style of masonry structures. Some arches of this class were built in the early days of the road on what is now known as the Chicago Division and also on the old main line from Freeport to Cairo. These arches for the most part failed and were replaced by timber trestles, the piles being driven through the crowns of the arches. Later most of these timber trestles have been replaced by concrete arches made after the modern standards or by I beam spans which have in turn been

replaced by the segmental, reinforced arch - a structure typical of the Illinois Central practice which will be detailed later.

Of the types of abutments and piers, the most prominent examples of the old masonry construction are: the Kankakee River bridge at Kankakee Ill, the Sangamon River bridge at Decatur and the Salt Creek bridge near Clinton Ill. The bridge at Kankakee is soon to be replaced by a concrete arch structure and eventually the others mentioned will either give place to entire structures of concrete, or to spans resting on concrete abutments and piers.

Reasons for Changing from Stone to Concrete.

The reasons which led to the change from stone masonry are:

1. No suitable stone for masonry is found along this line. The inferior quality of the local stone is shown by the failure of the early structures.

2. The cost of the best stone suitable for work on railroad structures, such as Bedford limestone, Cleveland sandstone and the limestones from the vicinity of Dubuque and Anamosa, Ia., is much in excess of that of concrete.

3. There is no object in using the stone masonry simply on the score of probable durability.

4. Crushed stone suitable for concrete work may be had at a reasonable rate and can be hauled long distances cheaply.

How effective these reasons were in causing the adoption of concrete by this road is shown by the amount of concrete work which has been done, to say nothing of that which is in contemplation.

In a paper prepared for the report of the Illinois Society of Civil Engineers and Surveyors for 1900, Mr. W. E. Engler outlines the work which was done by

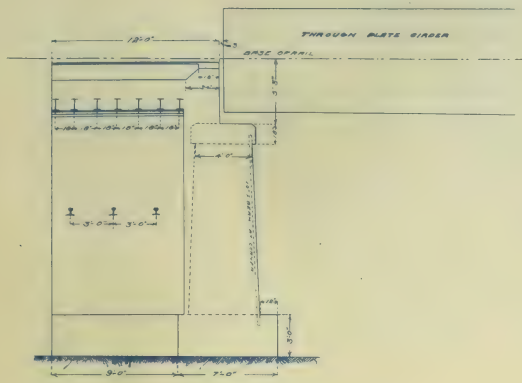
the Illinois Central in 1899: "At Normal, Ill., a single track through plate girder forty-two feet long on concrete abutments; near Apple River, Ill., an iron deck bridge of three spans on concrete abutments; and Erie; at Champaign, a fifty-foot through plate girder, three track span on concrete abutments. Near Council Hill, Ill., two pile trestles have been replaced by deck plate girder bridges having two thirty and one sixty foot spans each on concrete abutments and piers. Iron spans on concrete abutments were put in to replace two Howe trusses over the Menominee and Pecatonica Rivers." Since this work was done, many more structures such as, concrete arches, headwalls for pipe culverts, abutments for bridges, etc. have been built and as a matter of fact there were many of these in course of construction at the same time, as the structure of which the writer speaks.

In the southern states work has progressed more slowly owing to the work of grade reduction which has been going on, rendering the construction of permanent structures more difficult than it was north of the Ohio River. Still, at New Orleans on the Stuyvesant Docks much concrete work has been done in foundations, piers, etc.

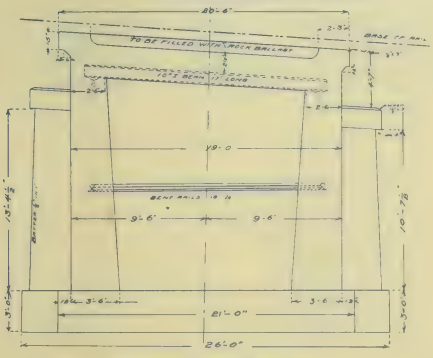
In general, by far the larger part of the concrete work done by the Illinois Central is bridge and culvert work. The bridge work includes tee-abutments, straight wall abutments, wing abutments, straight return abutments and piers. The culvert work consists of culverts, arches and head walls for pipe culverts.

Changes in Forms of Structures.

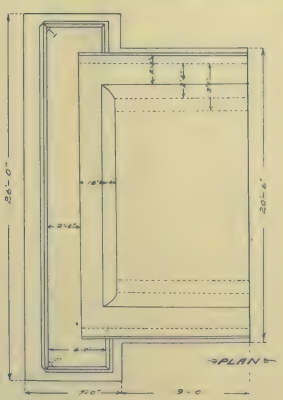
Bridge Abutments. The retaining plans for concrete abutments are, in general, the same as those for masonry, and except for the small changes made necessary by the changes in bridges used,



LONGITUDINAL SECTION



REAR ELEVATION

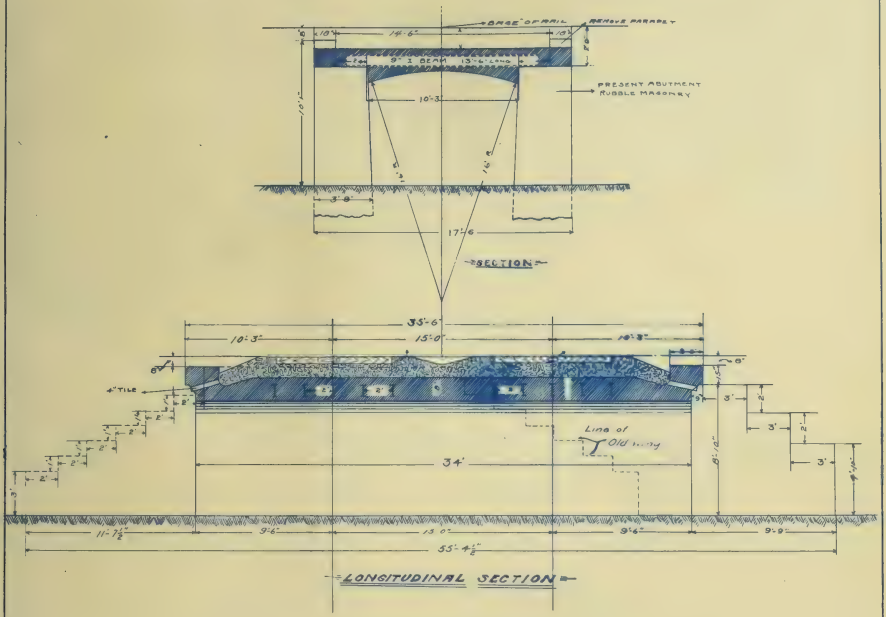


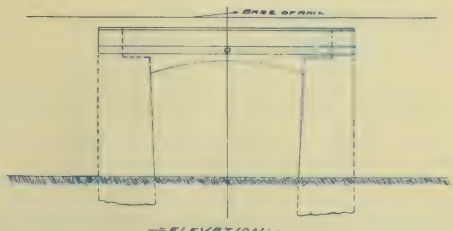
PLAN

CONCRETE T ABUTMENT
I.C.R.R. STANDARD
SHOWING TILTED BRIDGE SEAT
FOR USE ON CURVES

in Sarasota and coping the style of abutment is practically the same as that which has been used by the Illinois Central for many years. The tee abutments have been changed more by the adoption of concrete as a building material than the other forms and are more largely used than formerly.

The distinguishing features of this type are I beams imbedded in the concrete of the portions of the tee immediately under the track and tenk rails used as ties between the walls of the tee. The details of the crown have undergone some marked changes during the past three years; up to the middle of 1899 the width from out to out of the top of the tee was fourteen feet for single track; in the fall of 1899 this was changed from fourteen to sixteen feet and in the spring of 1901 this dimension was made twenty feet and six inches. The details are





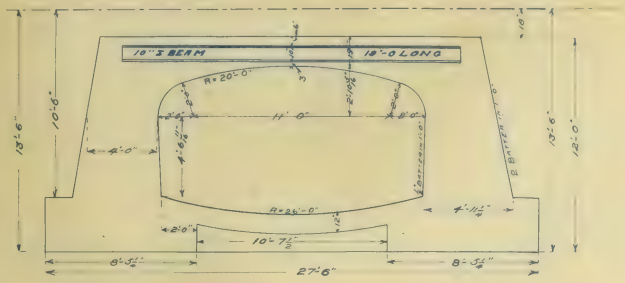
PLAN SHOWING METHOD OF CHANGING OLD I BEAM SPANS INTO FLAT ARCHES.
—I.C.R.R.—

shown in the diagram accompanying this paper. This width of tie makes a more presentable structure where the banks are high, and allows a truer alignment of track upon it. The other types are practically unchanged as to details.

Arches.

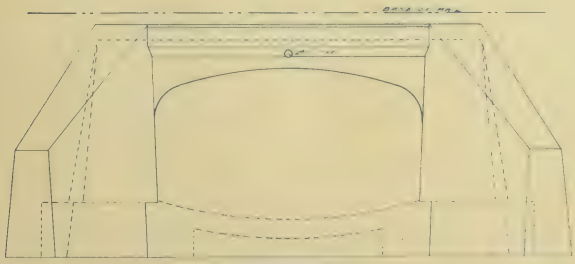
Segmental Reinforced Arch.

The segmental I beam reinforced arch is a structure peculiar to the Illinois Central, and is a development from the I beam girder span on concrete abutments. These I beam spans were transformed into flat arches by the introduction of concrete between and around the I beams. For openings where I beams would have been used, flat arches were designed which have developed into the standard segmental I beam reinforced arch. These arches are used for cattle passes and openings for small streams and ditches where the height of bank will not admit a standard semi-circular arch. The spans of these arches vary from



TRANSVERSE SECTION

LONGITUDINAL SECTION



ELEVATION

15 Ft. SEGMENTAL ARCH
Reinforced with I Beams.
I.C.R.R. STANDARD

eight to fifteen feet at the springing. Usually five I beams are placed under each bent. The size of beams used varies with the span. The following are the principal dimensions of the segmental arch shown in the accompanying diagram:

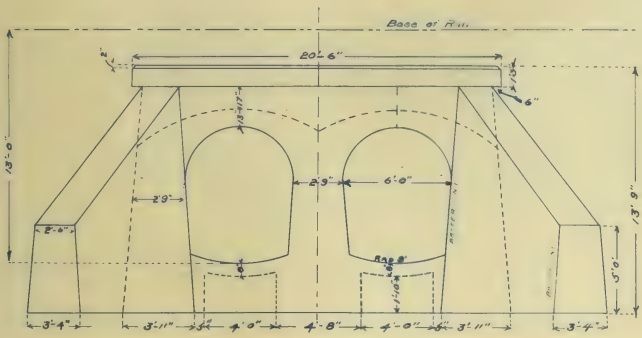
Span 15 ft., height, base of rail to footing, 10 ft. 6 in.; width of footing under bench walls 8 ft. 5¼ in.; total width of footing; 27 ft 6 in.; length, out to out of head walls, 34 ft.; height, footing to springing, 4 ft. 6 11/16 in.; depth of concrete under Is 3 in.; bottom width of bench walls 4 ft. 11¼ in.; number and size of I beams, 14, 10 in Is 19 ft. long; thickness of arch at crown 1 ft. 7 in.; depth of fallash 1 ft. 6 in.; coping 15 in. x 2 ft. 3 in. x 21 ft.; batter inside, ½ in. in 1 ft., outside 2 in. in 1 ft.; radii of arch, center, 20 ft., ends 2 ft.; radius of invert 26 ft.; thickness of invert 1 ft.; thickness of apron walls 1 ft. 6 in.; approximate contents 275 cu. yds.; approximate cost $1500.

The form of head walls for this type of arch varies according to conditions, some

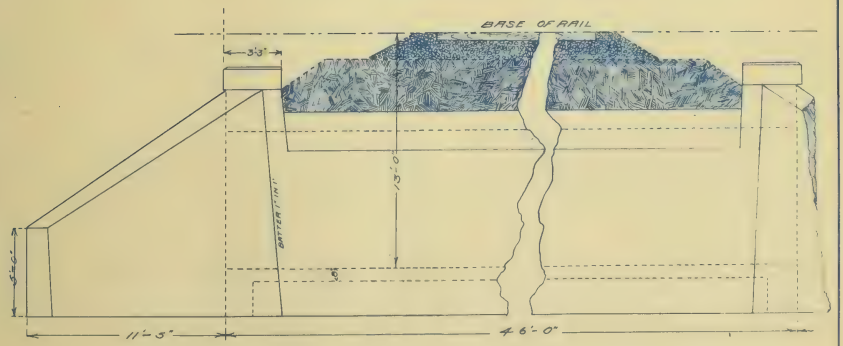
arches having wings parallel to the center line of the arch, some having wings set at an angle of thirty degrees with the axis, and still others at ninety degrees.

Semicircular Arch.

Another type of arch used for small openings, where the height of bank does not interfere, is the semicircular arch which is built in spans from six to twenty feet. In general form these arches are similar to the segmental arches with the exceptions of being semicircular and having no I beam reinforcement. With these arches the height of bank allows deeper filling between the crown of the arch and the track than with the segmental, reinforced arches and hence there is less danger of the arch crushing from the impact of trains. The smaller semicircular arches, six and eight foot, are sometimes built double, i.e., two six or eight foot openings are made, the arches having the same detail dimensions as the single structure.



FRONT ELEVATION



SIDE ELEVATION

DOUBLE 6 FOOT ARCH

I.C.R.R. STANDARD

A large number of these have been built to replace trestles and old stone arches and have proven to be very efficient structures. The principal difference between the new arches and the old ones lies in the fact that the monolithic construction renders the old form of paved or timber invert obsolete and makes possible forms of details that would have been very costly in the old forms.

The double six foot arch shown in the diagram opposite this page is one which was designed for a small stream near Adina, Illinois, and was built to place a stone arch of twenty foot span. This arch is representative of the standard double, semicircular arch and the details given are those used on all structures of this class

Large Arches

Of the larger arch spans having an opening of thirty feet or over the sixty foot elliptical arch over Rhodes Creek

near Jerry, Miss., is a notable example. This arch was one of the first long spans to be built of concrete by this company, and its construction has been followed by that of a number of other arches, ranging from sixty feet to one hundred and forty feet in span. The present steel bridge at Kankakee is soon to be replaced by a bridge consisting of concrete arches which will be one of the first of its kind in the west. The Little Wabash river near Watson, Ill., will be spanned by an arch of concrete which will replace a steel deck truss bridge on stone masonry abutments and piers. The designs of these arches are special and are not covered by company standards except as to general specifications as to materials used

Concrete used for Repairing Masonry.

Concrete has been used to a considerable extent in repairing old masonry and has produced excellent results in most cases. One of the most conspicuous pieces of work of this kind is that on the abutments of the bridge over Dismal Creek near Lacledе, Ill., which was built in 1886.

The old abutments were of the tie type, 9 ft. thick and 40 ft. long running back full depth into the embankment. The material up to the fourth course from the top is sandstone and above that, limestone, the top four courses having been added to raise the grade. These top courses had begun to show signs of disintegration and it was decided to repair the abutments by building a concrete coping to retain the ballast as shown in figure 2 on the next page. The concrete work was built in sections 6 ft. long which were bound together by steel rails imbedded in the

Fig. 1—Old Masonry, Dismal Creek Bridge, Ill. Cent. R. R.

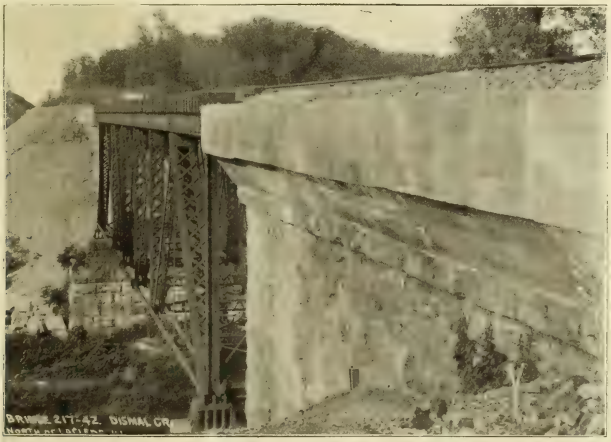


Fig. 4—Completed Work.

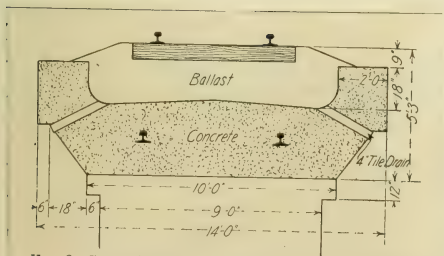


Fig. 2—Cross Section of Abutment and Concrete Coping.

Fig. 3—Sections of Concrete Coping.

concrete. The concrete coping which was added to the abutments not only replaces the stone courses which were removed but also protects the remaining masonry from water seepage and from drip on its face. The half tone illustrations of this work taken from the Railway and Engineering Review show the manner in which the work was done.

Other jobs of this kind have been done in various places along the line and considerable work in the way of jacketing old pieces of masonry with concrete has been done. Jacketing is of course rather expensive work, the concrete being deposited in thin layers about the old masonry and being made richer than concrete for ordinary work. The stairways at 60th St. Suburban Station, Chicago, were treated to a 3 in. jacket of concrete three years ago with excellent results.

Materials Employed.

Cement. In concrete work as done by the Illinois Central, various brands of cement are used, natural cements in foundation and Portland cement in body and face work. Natural cement is never used except in the footings. The company has in the office of the Engineer of Bridges, a testing plant in which all cement used is tested and rated. An experienced cement tester is constantly employed making tests of various cements, samples of which are submitted either by the manufacturers or by the inspectors on the several jobs.

The samples are tested for tensile strength at the ages of twenty four hours, seven days, twenty eight days, three months, six months, and one year. For immediate service the seven day test is used, although briquettes are made and tested at the several other periods named,

and when broken give more perfect information as to the material in any given structure. Roughly speaking, something over thirty five thousand briquettes have been broken in this office since the outfit was installed and the records are all on file. A Riehle Olsen machine is used in all tensile tests.

Other tests made are: the boiling test, test for fineness, specific gravity, and when possible, the freezing test.

The specifications for cement used are as follows, "Cement shall in all cases be approved by the Engineer of Bridges, and the inspector in charge of the work shall recieve a written approval before permitting concrete to be made from any cement delivered. Where possible, cement shall be delivered in time to have samples properly taken and sent to the office of the Engineer of Bridges, for making the usual one day and seven day tests of neat cement. Contractors shall provide storehouses at the site of the ser-

eral pieces of work in which to unload and store cement. Cement which is delivered on board cars must be unloaded promptly and stored in such warehouses, and the cars returned to the company's service. - - - -

Contractors shall be held responsible for the proper care of this cement, after it has been received and stored, and any cement injured through carelessness or neglect shall be rejected promptly by the inspector in charge.

No brand of cement shall be used in any concrete work which has not been accepted in writing by the Engineer of Bridges, such acceptance to be based upon regular tests, where possible.

The inspector shall from time to time, make small pats of pure cement and of cement mixed with sand to satisfy himself that the cement actually used is of uniform character, and has not been injured by exposure or in any other way;

and he may reject any cement which is wet or lumpy, or which fails to set properly in sample pats, and the contractor shall remove the same promptly from the work."

The above extract from the specifications covers the requirements for cement used. Some of the Portland cements most commonly used are; Chicago AA, Alsen's German, Sandusky, Atlas, Giant, Star and others of the same grade. The natural cements are; Utica, Louisville, Milwaukee, and on some jobs Chicago natural. Utica is however the one most commonly used.

Crushed Stone: The crushed stone most commonly used is limestone although on some jobs granite has been used and in one or two cases gravel. The specifications for crushed stone as used by this company are particularly complete and explicit as to the quality of stone used. In the specifications de-

fective limestone is divided into five classes all of which are to be rejected.

The classification is:

1. Stone containing more than one per cent of earthy or clayey matter.

2. Containing more than twenty per cent of fine stone or stone less than ½ in. in size

3. Containing more than five per cent of soft or rotten limestone which can be crushed with the fingers.

4. Containing more than ten per cent of flat stone larger than 2 in. in greatest dimension.

5. Containing more than fifteen per cent of crushed stone larger than specified — passing through a two-inch mesh.

The specifications further state: "If any of the five classes of defective stone above named can be modified by mixture with additional material or by breaking some of the stone by hand, its use

may be permitted under the direction of the engineer or inspector in charge."

Granite: Crushed granite is used for making coping, bridge seats, etc under the following specifications; "The crushed granite shall generally be of two sizes; (1) a fine crushed granite to be used as a substitute for sand, and (2) a coarser size, particles of which are not larger than 3/4 in. in greatest dimension, to be used as a substitute for crushed limestone in making bridge seats, pedestals, etc. All crushed granite shall be clean, entirely free from dust and earthy or clayey matter, and each grade shall be practically uniform in size. This material shall always be handled on platforms or in some way kept entirely free from admixture of earth, sand, etc.

Gravel: "The use of clean gravel in place of not more than one half of the specified amount of crushed stone may be permitted at the option of the chief

engineer or his authorized representative; but the work shall be done under such special instructions as shall be given in each individual case depending on the quality of gravel used and other existing conditions."

Sand: "Sand for concrete shall be clean and sharp (pit or bank sand being preferred), and sand shall not be rejected if containing occasionally small pieces of gravel. A sand is preferred that will not pass a sieve having thirty meshes to the linear inch. Sand shall be free from earth or alluvial matter; and when tested by stirring with water or rubbing in the hands shall not contain more than one half of one per cent of loam, clay or earth. No sand shall be used for the outside finish of any concrete, which contains small particles of coal or of lignite, although sand of this character may be accepted for foundations or for the interior por-

tion of any heavy piece of concrete work

Method of Measuring.

The sand and stone employed in the concrete are measured in headless and bottomless barrels or in bottomless boxes which are fitted with handles by which they may be lifted free from the sand and broken stone, or in square wheelbarrows especially designed for this purpose. The measurement of sand or stone in ordinary round bottomed wheelbarrows is not permitted. Cement is measured by the number of sacks used.

Specifications for Concrete.

Natural Cement: Natural cement concrete is used only in foundations and then only when the foundations are entirely below low water, or when there is no risk of the concrete being exposed to the action of the weather by the cutting away of the surrounding earth. It is not used unless a firm foundation is found after the excavations are com-

plete. In all cases where the foundation is liable to be exposed to the action of water or when the material in the bottom of the excavation is soft or of unequal firmness, Portland cement concrete is used.

The usual proportions in which natural cement concrete is made are, by measure, one part of approved cement to two parts of sand and five parts of crushed stone, all of which must meet the requirements of the specifications. When a stronger concrete is required the proportions of sand and crushed stone are reduced to two and four parts of sand and crushed stone respectively to one of cement.

Portland Cement Concrete: Portland cement concrete is used in bodies of piers and abutments, for wing walls and for the faced walls of arch culverts. The usual proportions by volumes are: one part cement, two and one half parts sand and six parts

crushed stone. Where, in the judgement of the engineer of bridges, special stringth is necessary for any part of the work, concrete in the proportions of one, two and five is used.

For arch rings, parapet head walls and copings for the same, Portland cement concrete in proportions of one, two and five is used. All concrete which is used in combination with iron work subjected to transverse loading is made in the proportion of one, two and five.

Coping: "Granitoid" is used for bridge seats and copings which carry bridge pedestals and is made of Portland cement and granite in the proportions of two parts of fine granite screenings and three parts of coarser granite screenings, not exceeding 3/4 in. in greatest dimension, to one part of Portland cement.

Mixing.

"All concrete must be mixed on substantial platforms of plank or boards

securely fastened together, so that the various materials of the concrete can be kept entirely free from admixture of foreign matter. Hand mixed concrete shall not be made in batches of more than one cubic yard" The details of mixing by hand as required by this company's specifications are as follows: "The proper amount of sand is measured and spread upon the mixing board and the proper amount of cement is spread upon the sand, the sand and cement are then turned over dry either with shovels or hoes until they are thoroughly mixed. The mass is then wet and made into a "rather thin mortar" and is then spread into a uniform thin layer upon the board. The proper amount of crushed stone after having been previously wet is then spread upon mortar and the whole mass is turned at least twice, usually three times, with shovels or hoes. It is then taken to the work in wheel bar-

rows or is shoveled directly into place as the case may require. In wetting the concrete a sprinkling can is usually used as it is not permitted to use a jet or to dash the water on from buckets.

The proper working consistency as required under these specifications is such that when thoroughly rammed, the concrete will quake slightly but that it shall not be so thin as to quake in the barrow before ramming.

Machine Mixing: Up to the past two years most of the concrete used by the Illinois Central was mixed by hand, very few machines being used in this work, but during the last season much machine mixing has been done. The McKelvey power mixer has been used quite extensively by most of the contractors. Hand mixers made by the same extent by one or two contractors during the season of 1900 but owing to the fact that the men were more used

to shovel mixing, the mixers were not as efficient as they were expected to be and although there were a number of machines on various pieces of work they were not used. The power mixers however have proven more efficient and are now used by all the contractors who are building concrete work for this company.

The specifications for machine mixed concrete are as follows; "Machine mixed concrete shall be made of the same general consistency as hand mixed concrete. Proper precautions shall be taken to see that the requisite proportions of the different ingredients are used. If the machines used are not provided with devices to deliver each of them, the process of making the concrete shall be as follows; the proper amount of sand, cement and crushed stone for a batch not to exceed one yard of concrete shall be delivered on the platform and roughly mixed together so that when the dry mass is cut

down and delivered to the mixer by means of shovels, proper amounts of each ingredients are handled at each shovelful. It will not be regarded as satisfactory to to deliver crushed stone, sand and cement at random to the mixer without taking special means as above described to insure the delivery of the proper quantities of each ingredient as nearly as may be simultaneously."

Forms.

The forms used in building concrete work are built of material furnished by the contractors and are paid for in the general estimate as concrete. The material required by the specifications for the facing of all molds is two inch plank sized to one and three fourths inches thickness, but on several jobs three fourths inch flooring lumber has been used with rather a bad effect on the appearance of the pieces of work on which it has been used. The weight of the concrete and

the ramming having bulged the forms quite badly in some cases while in others the cracks between the planking have left markings on the faces of the work which do not improve its appearance. Generally speaking, however the forms need have been very substantially built of two inch lumber tied together with twisted wire ties which are left imbedded in the work. being cut off far enough from the face of the work to allow a smooth, unmarked surface to be made. Methods of tying forms which are recommended by the specifications are; "Tie rods having sleeve nut connections which will permit the removal of the projecting ends of bolts, or rods etc, leaving only small holes in the surface which may be stopped up with pointing mortar after removing the forms." Another system is to tie the projecting ends of the studding front and back with twisted wire ties which are removed and raised as the concrete

work reaches them. The studding used in building the forms is spaced not more than four feet apart when two inch lumber is used.

For projecting copings, bridge seats, parapet walls, and all finished work the forms are made only of dressed lumber and are more substantially braced and tied than for ordinary work. The surfaces of these forms are often soaped or oiled to give them a smooth finish. The tops of copings, wing walls and the like are finished with trowels in the same way as are concrete walks, floors etc.

Foundations are often put in without the use of forms in places where the soil is firm enough to stand the amount of ramming necessary to insure good, solid foundations.

Placing Concrete.

The concrete for all work on abutments, piers and arches is deposited in

six inch layers and wherever possible each separate layer is completed before another is started. It is not allowed to taper the end of a layer off to the level of the next lower layer but when it is not possible to complete one layer across the entire work it must end squarely, a plank of the desired height being held firmly against the end of the layer. It is required that concrete be mixed as near as possible to the place in which it is deposited in order that it may not require handling other than tamping after it is dumped in the forms.

Facing.

A facing mortar consisting of one part of cement, by measure to two parts of sand is put in next to the forms to make a finish for all parts of the work which are liable to be exposed to the weather. The method used for securing the exact thickness of this facing, one and one half inches, is as follows; a piece

of sheet iron six inches in width — the height of a layer of concrete — and of any convenient length, say six feet, having small angle irons, the projecting legs of which are one and one half inches in width riveted to its face at intervals of about two feet, and provided with handles standing above the upper edge at or near each end, is used. This piece of iron plate if placed with the projecting angles against the face of the form, will leave a space of one and one half inches between the plate and the form. This space is filled and tamped with a shovel or other tool to insure complete filling of the whole space, the layer of concrete in the body of the work is backed up against the plate and the plate is removed and the entire mass rammed in one uniform layer. The mortar for facing is made of such a consistency that it will flow somewhat freely.

Pointing

When small pits or openings are left in the face of concrete work they are pointed with a mortar made of one part of cement to one part of sand mixed in small quantities as needed. This pointing mortar is used on any surface, whether to be left exposed or not, where there are any pits or scarsit being the intention not to leave any pitted or honey combed surfaces on any part of the work.

Cost of Work.

As nearly all the work done by this company is by contract it is difficult to obtain definite prices paid for the various pieces of work done. Some of the smaller isolated jobs are done by the bridge gangs on the several divisions but there is no definite record as to the price per yard of the work; the cost being charged as labor and material only. The general prices given here are fair averages

of the prices paid for contract work although for special jobs the prices may vary slightly above or below those given. The work for which these prices are given was done during 1899 and 1900

Cost of Concrete, I. C. R. R.

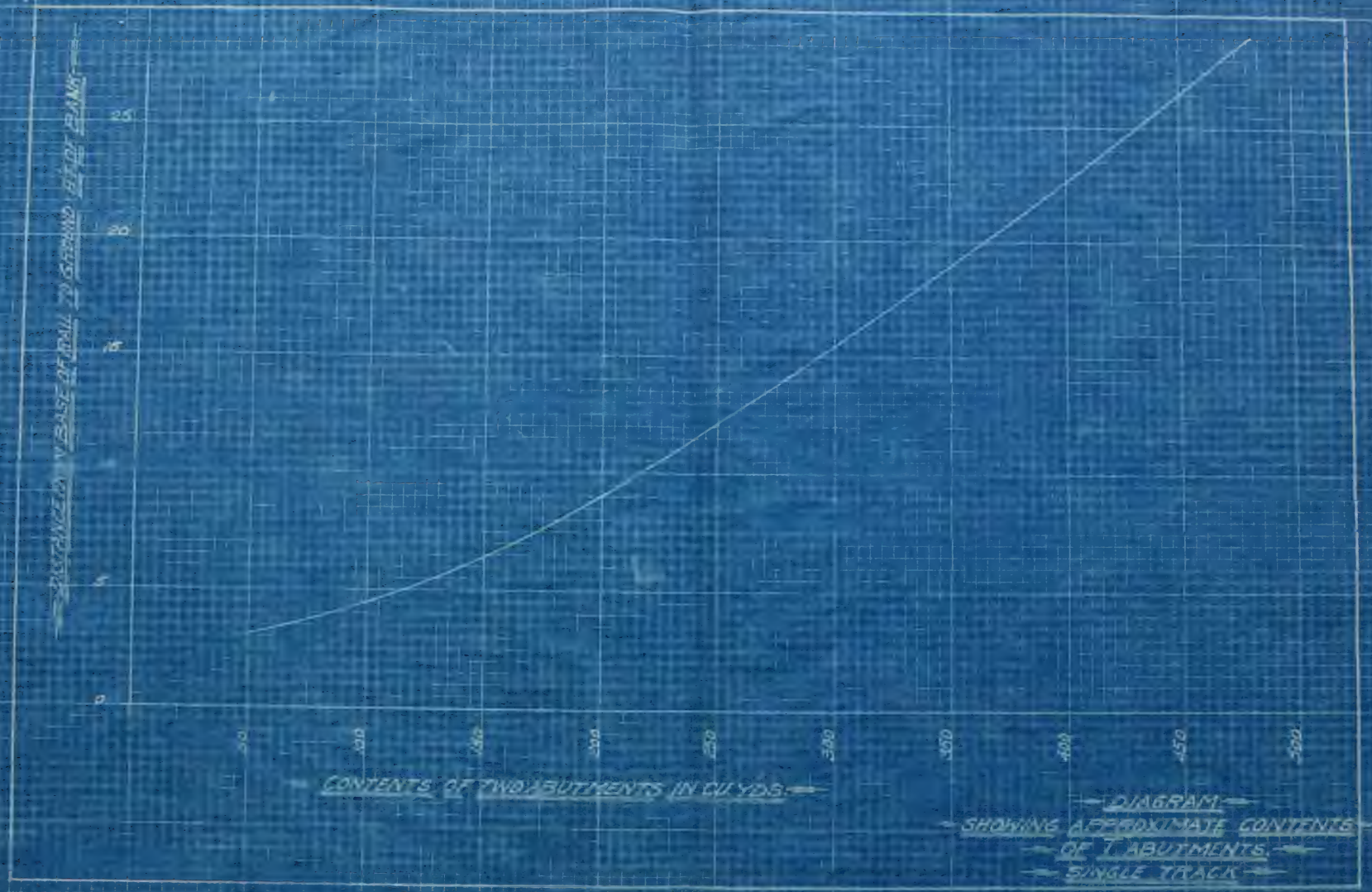
Cement	Proportions			Cost in Place
	Cem.	Sand	Stone	
Natural	Not	Given		$2.75 to $3.60
Portland	1	2½	6	5.00 to 5.50
"	1	2	5	5.50 to 6.20
Jacketing				
Portland	1	2	5	7.50 to 8.00

It is usual in making rough estimates of work to assume a cost of $6.00 as being about the cost of completed work.

For these rough estimate of quantities and cost a rather interesting set of curves has been prepared which give the approximate contents of abutments in cubic yards. These curves were prepared on the assumption that the contents

were a function of the height of bank and in the curves the ordinates are taken as height of bank and the abcissae as cubic contents in yards. The quantities given are of course only approximate and are only used in roughly estimating a piece of work. The results however are within two or three per cent. correct for the kind of abutments shown.

The writer wishes to acknowledge his indebtedness to the officials and employees of the Illinois Central for their help and to Professor Baker for his kindly suggestions in the preparation of this thesis.


HEIGHT OF BASE OF RAIL "A" GRADE STOP PLANK
25
20
15
5
0
50
100
150
200
250
300
350
400
450
500
CONTENTS OF TWO ABUTMENTS IN CU YDS
DIAGRAM
SHOWING APPROXIMATE CONTENTS
OF T ABUTMENTS
SINGLE TRACK

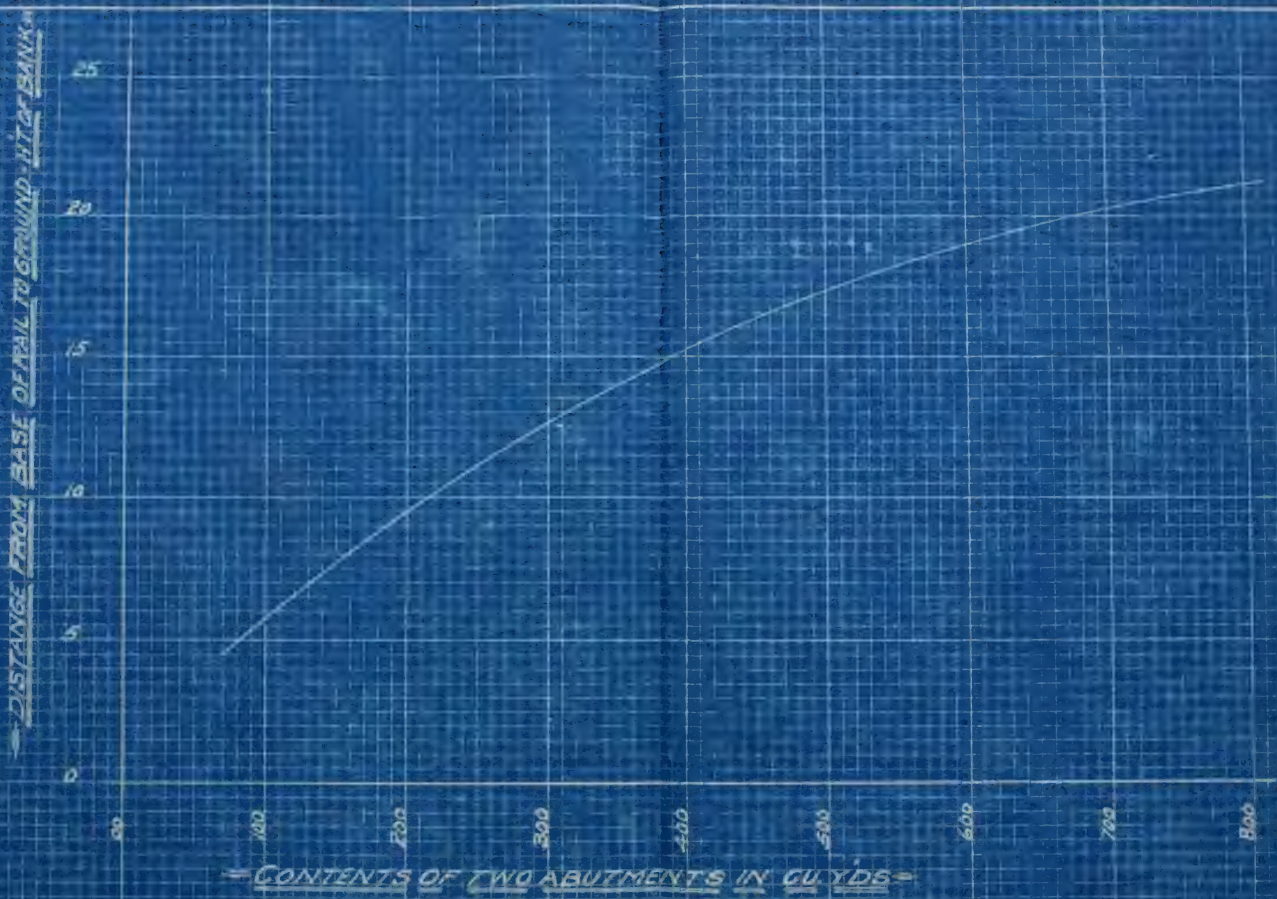


DIAGRAM
SHOWING APPROXIMATE CONTENTS
OF STRAIGHT ABUTMENTS
SINGLE TRACK